

**Efficacy of baiting as a technique for monitoring arthropods as indicators of meadow change in Sierra Nevada Network Parks**



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## Summary

The Sierra Nevada Network initiated an agreement with the University of California White Mountain Research Station to assess invertebrates as indicators of meadow change. Additional baseline ecological data on the meadow invertebrate assemblage was needed prior to testing response of projected invertebrate vital signs to meadow change. Particular needs included information on fine-scale temporal changes through the growing season, more intensive aquatic phase sampling, comparative sampling in both subalpine and montane meadows, assessment of relationships between invertebrates, vegetation, and physical parameters, and evaluation of wilderness-friendly monitoring techniques. Most of these relationships have been explored in a previous pre-project report/literature review and several progress reports. This document reports on an assessment of baiting as a monitoring technique for use in Sierra meadows.

This project compared invertebrate collections from ten series of bait stations in Tuolumne Meadows (Yosemite National Park), each including a honey, tuna, and a peanut butter bait, and ten co-located vacuum net samples. These collections were supplemented with some bait stations in nearby meadow habitats. Baits were placed on weighted cards prior to vacuum netting. Insects were removed from the baits individually with forceps after 30 minutes. We

used the same vacuum netting techniques that we have employed in a number of related Park Service projects over the last seven years. Bait response variables included overall ant abundance, abundance by ant species, and ant species richness, and vacuum net response variables included order, family, and ant species abundances.

Almost all animals attracted to the baits were ants. Overall ant abundances were greater on tuna than on honey or peanut butter, and species richness was highest on honey and on tuna. Catch of individual ant species varied with bait type, but honey and tuna were more effective than peanut butter in attracting multiple taxa. As expected, vacuum samples collected a much greater diversity of fauna than baits at both the order and family levels. Vacuum sampling collected all taxa found on baits and also collected one specimen of an ant species, *Leptothorax muscorum* complex, not collected by baiting.

We believe that the best balance of efficiency and assemblage description will be offered by use of separate honey and tuna baits for the Meadow Ecological Integrity vital sign initiative. These two bait types in combination included all taxa collected by baiting, and only about ten minutes will be required for all field work involved with both honey and tuna baits.

## Introduction

National Park Service (NPS) policy and recent legislation (National Parks Omnibus Management Act of 1998) requires that park managers know the condition of natural resources under NPS stewardship and monitor long-term trends in those resources in order to fulfill the NPS mission of conserving parks unimpaired. The NPS has developed an Inventory & Monitoring program to fill knowledge gaps in baseline data on natural resources in Parks and to design and implement long-term (Vital Signs) monitoring that will enable managers to develop broadly-based, scientifically sound information on the current status and long term trends in the composition, structure, and function of park ecosystems (Fancy 2003).

The Sierra Nevada Network initiated an agreement with White Mountain Research Station to assess invertebrates as indicators of meadow change. Meadows are of high interest for monitoring as these habitats concentrate resources, provide critical habitat for both resident and transient animals, and have been identified as key ecosystem elements in the Sierra Nevada Network Parks. A powerful indicator of the status of meadow ecosystems is found in the invertebrate assemblages that use meadows for all or part of their life cycles. Meadow invertebrates are ideal candidates for monitoring, because these animals 1) include representatives of several trophic levels and are important

food resources and processors of organic material, 2) represent a “crossroads” for ecological flows, e.g., aquatic-terrestrial, 3) are easy to sample quantitatively, and 4) are sensitive to a variety of stresses and in turn are capable "vectors" for cascading disturbances (Holloway 1980, Rosenberg et al. 1986). In particular, invertebrates are sensitive to trampling pressures (e.g., Liddle 1975, Hylgaard 1980) and arthropod populations can be reduced by nearby trails in the Sierra (Holmquist & Schmidt-Gengenbach 2004). Invertebrates are also extremely sensitive to pesticides, herbicides and other contaminants (Curry 1994, Cilgi & Jepson 1995, Scholtz & Krüger 1995, Longley & Sotherton 1997, Ellsbury et al. 1998, Stewart 1998).

Additional baseline ecological data on the meadow invertebrate assemblage were needed in order to establish potential metrics for use as vital signs. Particular needs included information on fine-scale temporal changes of the invertebrate assemblage through the growing season, more information on aquatic phase fauna, assessment of relationships between invertebrates and vegetation, determining differences in assemblage structure between subalpine and montane meadows, and documenting correlations between a broad suite of physical parameters and fauna. The ecological information gleaned from this initial pilot work will provide necessary background for selecting parameters that will ensure efficiency of vital sign usage (Andersen & Majer 2004). This work

has also identified potential cost savings via timing of sampling, sampling and sample sorting methodologies, taxonomic resolution, and choice of efficient response variables.

This report explores the efficacy of baiting as a monitoring tool for use in Sierra meadows. Baiting (Bestelmeyer et al. 2000, Delabie et al. 2000) targets ants and may also collect other taxa (Alonso 2000, Andersen and Majer 2004). Baiting is the most common method for monitoring ant assemblages (Bestelmeyer et al. 2000) and has a number of advantages for sampling remote areas. The materials are light in weight and easily transportable. Baiting is easily demonstrated to field crews, creates no wilderness issues, integrates collection over a wide area, and produces samples that require no sorting. Baiting can also be used in areas that are heavily saturated but not flooded. These habitats, which are common in montane wetlands such as the Giant Forest in Sequoia National Park, are not sampled well by vacuum netting and yet cannot be sampled with aquatic techniques (Holmquist and Schmidt-Gengenbach 2006a).

This project took advantage of a contemporaneous project in Tuolumne Meadows, Yosemite National Park, that was making use of vacuum sampling to assess trampling impacts (Holmquist and Schmidt-Gengenbach, unpublished; cooperative agreement #H8R07010001). Baiting efforts were paired with

vacuum sampling on control plots of trampling addition experiments, allowing comparison of the two techniques at relatively little cost. Although we anticipated baits to primarily attract ants, we also sought to determine the extent to which other taxa might be monitored with this technique.

## Methods

*Baiting.* Ten paired bait-vacuum net samples were collected during the height of the growing season when arthropods are most abundant in Tuolumne Meadows in Yosemite National Park (Holmquist and Schmidt-Gengenbach 2006a; Table 1). Plots were dominated by various combinations of *Carex filifolia*, *Calamagrostis muirii*, *Ptilagrostis kingii*, and *Juncus balticus* (see Holmquist and Schmidt-Gengenbach 2006a for further information on the invertebrate and plant assemblages in this area). We supplemented these paired samples with bait-only sampling at Dana Meadows, Crane Flat, and May Lake, also all in Yosemite National Park (Table 1).

Tuna or sardines are the most commonly used baits for monitoring ants, although baits that have higher carbohydrate content, such as honey, peanut butter, jelly, cookie crumbs, or sugar solutions are also used alone or in combination with proteinaceous baits (Bestelmeyer et al. 2000). We used one tuna, one honey, and one peanut butter bait at each site. We placed baits prior to any other work on the plot to avoid disturbance. Baits were in place on each plot for 30 minutes.

We tested various means of collecting ants from baits, including use of an aspirator, placing the entire bait card in an alcohol jar, and direct collection of animals from the baits with delicate, flexible forceps. The latter approach was

fastest, lost the fewest animals, and was the least equipment intensive.

We placed baits on cards made of heavy weight, green construction paper (Art Street, Riverside Paper Company). We used three 8x16cm sheets per site (one for each bait type; Fig. 1). Use of paper instead of plastic allows liquids to soak through to the other side of the paper, potentially allowing more taxa to be present at the bait. More dominant taxa may appear on the bait lying on the paper, while less aggressive species may be able to access the bait that has soaked into the bottom of the paper (Bestelmeyer et al. 2000).

Prior to sampling each site, three rocks (~5cm diameter and ~100g) were located for use in weighting the bait cards to prevent loss due to wind. Bait locations were chosen randomly at each site with the stipulation that baits be placed at between three and five meters from the vacuum plot.

The honey bait card was weighted with a rock on one end, and a 15mm diameter puddle of honey was created in the center of the card at the opposite of the card from the rock (Fig. 1). This puddle will expand in the heat (left cover photo). The tuna card was also placed randomly, with the additional stipulation that this bait be placed at least 2m from the honey bait. A plastic spoon was used to apply about one cubic centimeter of tuna (Fig. 2). Lastly, a peanut butter bait was placed via the same procedure. A plastic knife was used to apply about one square centimeter of peanut butter (Fig. 3). The time was

noted on the data sheet and a watch alarm set for 30 minutes. At this time, vacuum netting (see below) and other work proceeded on the plot, while minimizing disturbance, particularly near the baits, in order to allow ant foraging trails to remain relatively intact.

When the alarm sounded, one worker slowly approached the honey bait holding forceps and an appropriate pre-labeled vial. Approach was made with a minimum of disturbance and while avoiding casting a shadow on the bait. A count was made of the number of ants present at the bait. The vial was uncapped, and the ants were removed from the bait singly with the forceps and placed in the vial. Escapees were noted. The same procedure was then used for the tuna bait and lastly for the peanut butter bait. See Holmquist and Schmidt-Gengenbach (2006b) for further details on baiting methodology.

*Vacuum netting.* We sampled terrestrial habitat with a vacuum net apparatus (Fig. 4). Vacuum sampling has been found to be most efficient when used with some form of enclosure box which is placed prior to suctioning (Henderson and Whittaker 1977, Hower and Ferguson 1972, Harper and Gwynn 1998), although enclosures are often not used.

Despite the general efficiency of vacuum sampling, this method has not worked well in capturing rapidly-moving insects (Powell et al. 1996). The operator creates disturbance, and even if an enclosure box is used, flying and

other vagile insects will flee the area before the enclosure is placed. We used a 0.5 m<sup>2</sup> steel quadrat with a conical mesh covering to minimize escape by mobile fauna (Holmquist and Schmidt-Gengenbach 2002; Fig. 4). The mesh cone has an elasticized hole at the apex through which a vacuum intake tube can be inserted. This quadrat is thrown toward the target area from a distance and staked in place to form a seal with the substrate. The vacuum intake is then inserted through the mesh aperture for sampling (Fig. 4).

We used a Craftsman 320 km/h gasoline vacuum modified with a nylon “no-see-um” mesh (0.25mm) collecting chamber inserted in the intake tube in conjunction with the netted quadrat (Fig. 4). After staking the quadrat, we made multiple passes through the vegetation with the vacuum intake from different orientations over a four-minute period. The intake was then extracted from the quadrat, the integral mesh collecting bag was removed from the intake tube, and the fauna and litter were transferred to a re-sealable plastic bag and placed on ice as soon as possible.

Sorting was done in the laboratory. Ants were identified to species; other taxa were identified to family.

We compared overall ant abundance, abundance by ant species, and ant species richness using paired two-tailed t-tests in SYSTAT (SYSTAT, Inc. 1992). Many zero and near-zero values occurred, and we  $\log(y+1)$  transformed to meet

parametric assumptions. Tests were not performed for comparisons of catch from multiple bait types, e.g., honey + tuna versus honey + peanut butter, because of lack of independence.

## Results

No taxa other than ants were collected from the Tuolumne bait stations, although a small number of flies and grasshoppers flew upon approach. Across the ten bait stations, two flies flew from honey bait cards, and two flies and two grasshoppers flew from tuna bait cards.

Overall ant abundances were greater on tuna than on honey or peanut butter (Fig. 5), although differences among bait types were not significant due to high variance in catch (Fig. 5; HvT:  $p = 0.37$ , HvPB:  $p = 0.69$ , TvPB: 0.32). In the ten replicate bait series, ants were found on the honey baits three times, on the tuna baits four times, and only once on the peanut butter baits, although this one occurrence yielded the highest single-bait catch observed in the study: twelve *Myrmica discontinua*. The largest catch on honey was four ants, and the highest on tuna was eight ants. Adding the catches from the bait stations in various combinations increased the total ant catch and surpassed the number of ants per meter squared collected by vacuum netting (Fig. 5).

Species richness was highest on honey and on tuna (Fig. 6), although these differences relative to peanut butter were again non-significant (HvT:  $p = 0.83$ , HvPB:  $p = 0.29$ , TvPB: 0.19). Ant species richness as determined by honey and tuna baits was comparable to that derived from vacuum netting (Fig. 6). With one exception, multiple species were not collected from any single

bait. This exception was a single honey bait with one *Formica* sp. cf. *occulta* and two *Formica lasioides*. Adding catches from multiple bait stations increased the species yield; the highest overall species richness was derived from (honey + tuna) and (honey + tuna + peanut butter) (Fig. 6).

Catch by species varied among bait types (Fig. 7). All species collected on baits, except *Formica* sp. cf. *argentea*, were collected on honey, albeit in relatively low numbers. *Myrmica discontinua* and *F. lasioides* were not collected on tuna, but this bait was the only one that yielded *F. argentea*. *Myrmica discontinua* was the only ant collected on peanut butter; as noted above, this species was collected in large numbers on a single bait. None of the differences in species abundances by bait type were significant, with the exception of course of comparisons between positive and zero values. When catches from all possible bait combinations were added, (honey + tuna) and (honey + tuna + peanut butter) were the only combinations that represented all ant taxa collected by baits. Remarkably, the ten vacuum net samples collected a single specimen of each of the four taxa collected by baiting, plus a single specimen of a species not collected by baiting, *Leptothorax muscorum* complex, yielding both a mean and standard error of 0.4 for each species after conversion to per meter square values (Fig. 7).

Supplemental late-season baiting at Dana Meadows, Crane Flat, and May Lake failed to yield any ants. However, a silphid beetle, *Heterosilpha ramosa* (Fig. 8), was collected on tuna at Crane Flat, and a carabid beetle, feeding on liquid seeping through to the bottom of the same bait card, escaped capture.

Vacuum samples collected a much greater diversity of fauna than baits at both the order and family levels (Figs. 9, 10). Eight orders and 20 families were represented. Samples were dominated by Diptera (Fig. 9), particularly sphaerocerids and drosophilids (Fig. 10).

## Discussion

The methods investigated in this report were primarily targeted towards ant monitoring. Ants have had great success as indicator groups in terrestrial systems (e.g., Greenslade 1978, Andersen 1990, 1993, 1997, Alonso 2000, Majer and Nichols 1998, Andersen and Majer 2004). Much of this utility is because ants meet Hellawell's (1986) criteria for desirable indicator taxa:

- 1) Reasonable, but not overwhelming diversity
- 2) Well-known taxonomy
- 3) Ease of sampling
- 4) Abundance
- 5) Wide distribution in the target ecosystem
- 6) A mixture of ecological roles

In addition, ants include specialist taxa and are responsive to changing environmental conditions (Majer 1983, Kaspari and Majer 2000). Erhardt and Thomas (1991) found ants to be three times more responsive to environmental change than the plants with which the formicids were associated. Use of ant genera, rather than species, can also be efficient when necessary (Andersen 1990).

There is an additional benefit to use of ants as one of a suite of invertebrate vital signs: ants are among the most dangerous invasives that threaten natural systems (New 1995). Almost ten percent of California's 281 ant species are non-native (Ward 2005). Monitoring ants would provide early detection of destructive exotic species such as the Argentine ant and red imported fire ant that may threaten the Sierra Nevada ecosystem.

This pilot project indicates that baiting will be useful for monitoring ants, and the attraction of beetles at Crane Flat suggests that at least some beetle catch can be expected as well. Although flies were attracted to baits, capture will in general not be possible. The observed grasshoppers appeared to be resting on the cards rather than attracted to the baits. Baiting is of course not expected to produce the broad spectrum of taxa collected by vacuum netting. However, baiting in conjunction with sweep netting (Holmquist and Schmidt-Gengenbach 2006c) should collect most of the taxa sampled by vacuum netting (Holmquist and Schmidt-Gengenbach 2006a) and yet not pose a problem in terms of wilderness issues.

Ant abundances in Tuolumne meadows, as indicated by vacuum netting, were low in 2006 (2.0 per square meter) versus 2004 and 2005 (8.3 and 10.9 per square meter, respectively; Holmquist and Schmidt-Gengenbach 2006a). Abundances of most taxa, with the exception of Diptera, were low in 2006.

This low abundance was unfortunate given the necessarily limited spatial and temporal extent of the bait testing.

We believe that the best balance of efficiency and assemblage description will be offered by use of separate honey and tuna baits for the Meadow Ecological Integrity vital sign initiative. These two bait types in combination included all taxa collected by baits. Use of both tuna and honey will provide both a proteinaceous and carbohydrate bait, which can be advantageous for collecting as many ant taxa as possible (Bestelmeyer et al. 2000). Little additional time will be required to set two baits instead of a single bait. In turn, we believe that use of peanut butter as a third bait would not provide sufficient benefit to justify the additional effort. Setting and collection of two baits will require no more than ten minutes total. Use of a second bait will however significantly increase time required for taxonomy.

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Fig. 1. Construction paper with honey bait weighted with rock.



Fig. 2. Construction paper with tuna bait.



Fig. 3. Construction paper with peanut butter bait weighted with rock.



Fig. 4. Tossing the netted quadrat and vacuuming fauna from vegetation through the elasticized aperture in the net. L. Greene photos.

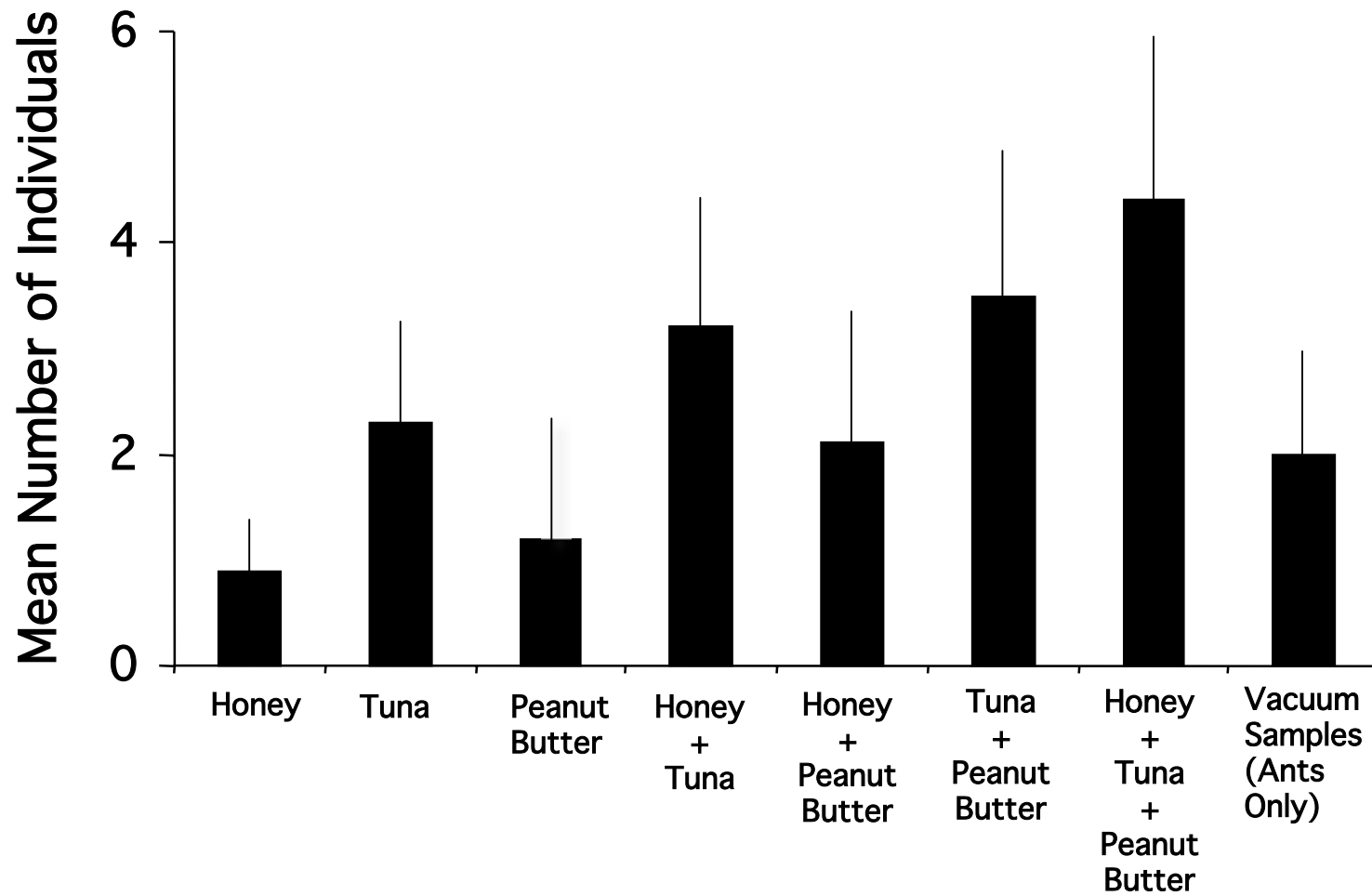


Fig. 5. Mean (SE) ant abundance for baits and paired vacuum samples (n= 10).

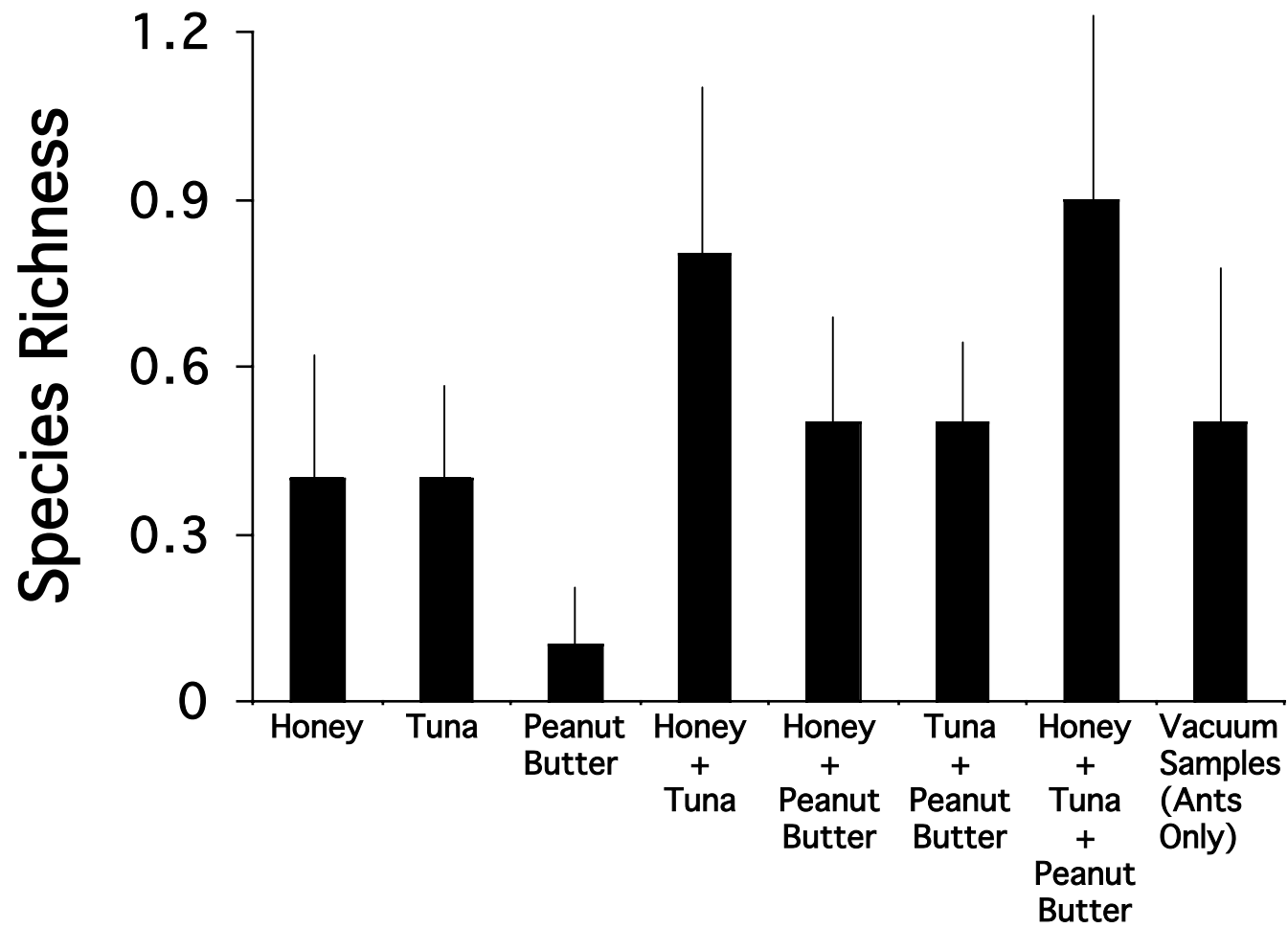


Fig. 6. Mean (SE) ant species richness for baits and paired vacuum samples (n= 10).

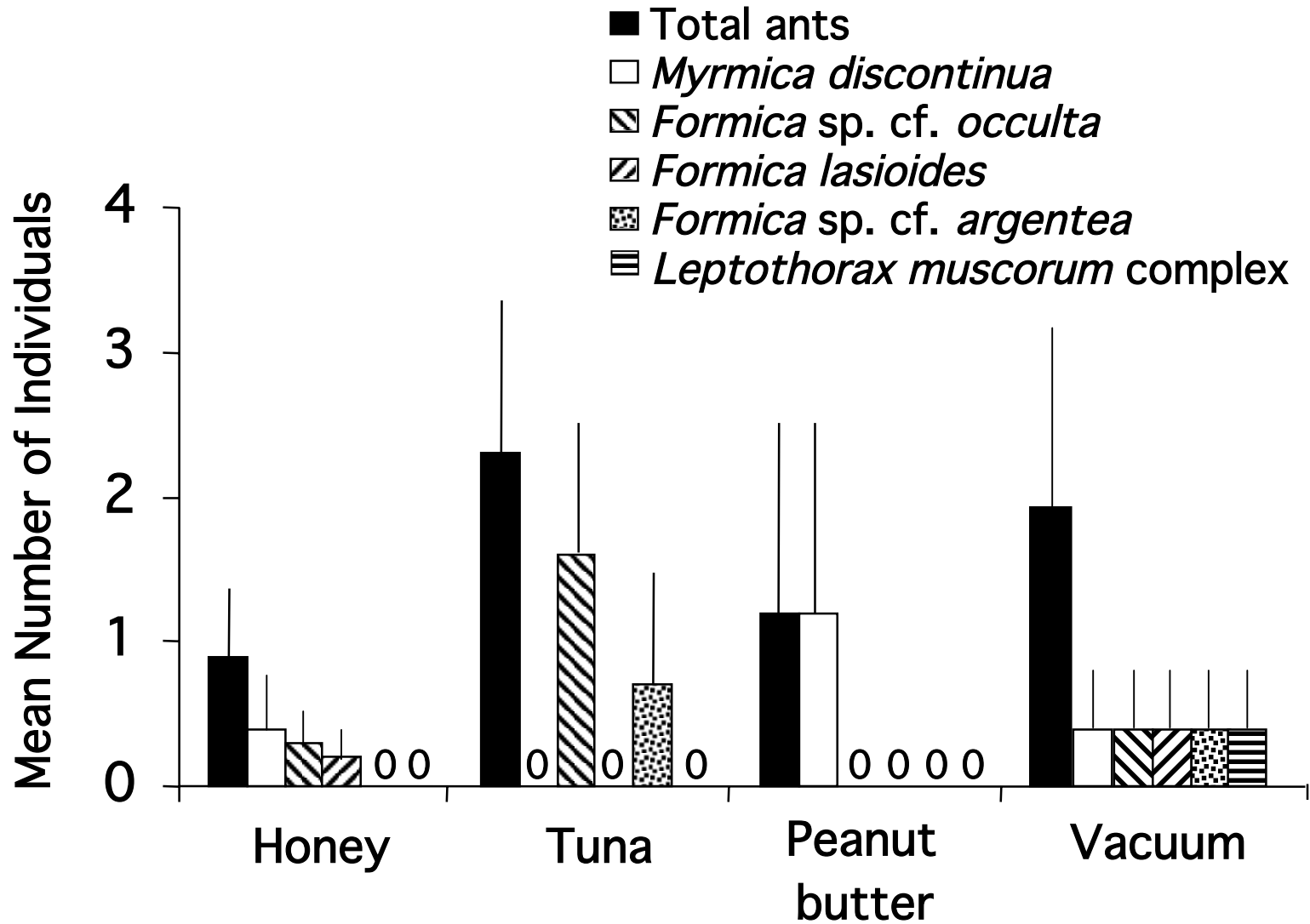


Fig. 7. Mean (SE) ant abundance (total and by species) for different bait types and vacuum netting (n= 10).



Fig. 8. *Heterosilpha ramosa* collected on tuna at Crane Flat.

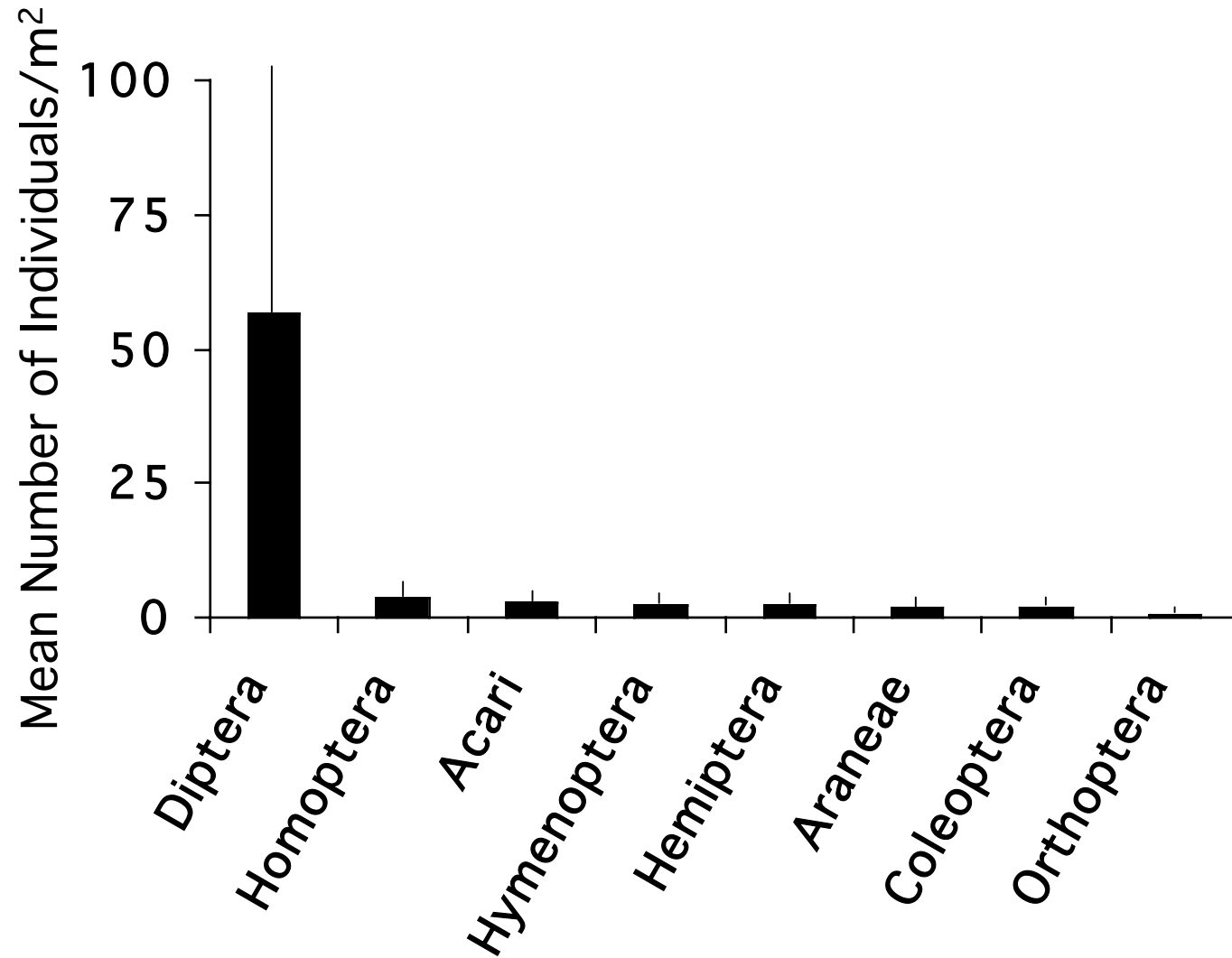


Fig. 9. Mean (SE) abundances by order for vacuum net samples (n= 10).

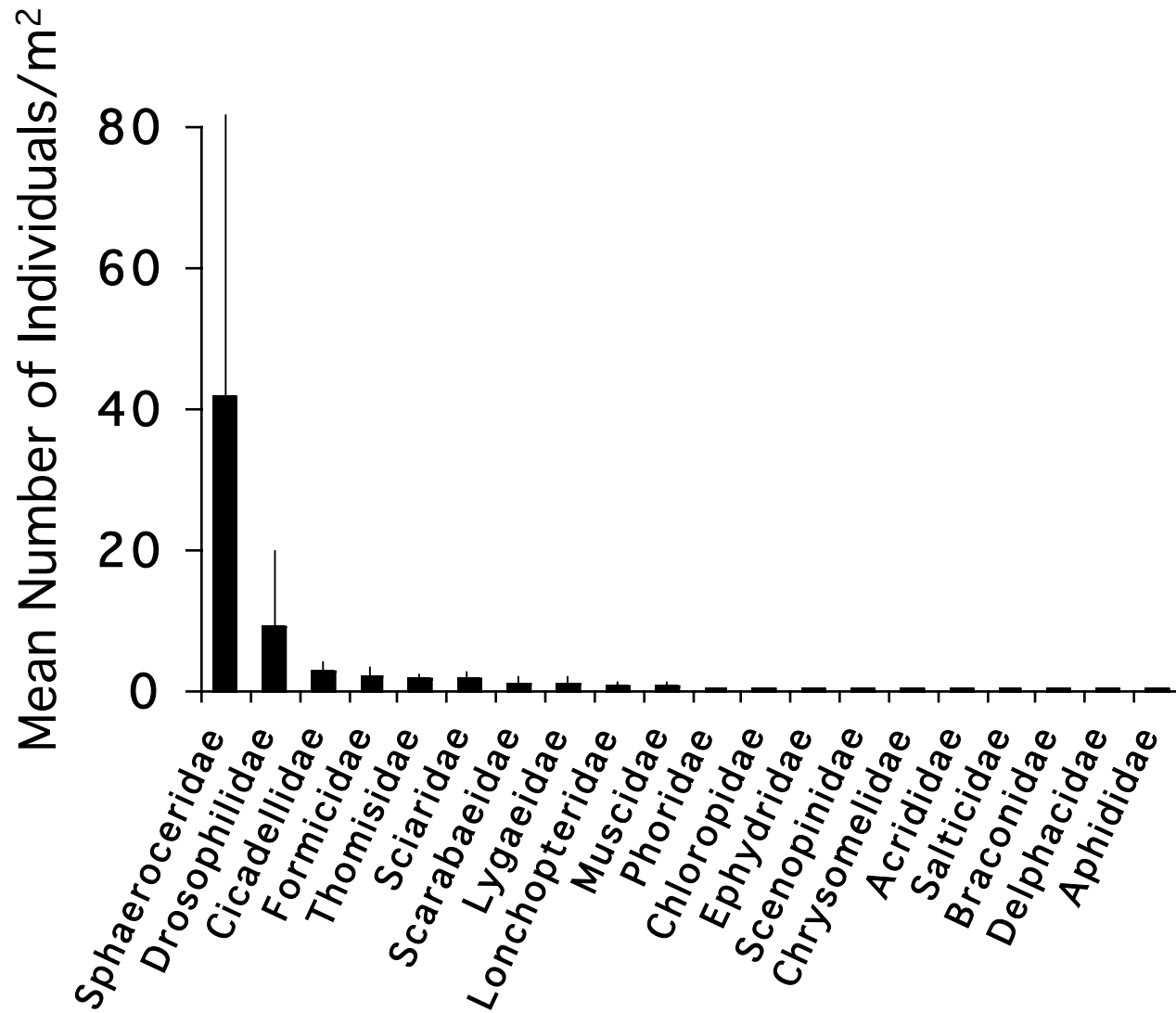


Fig. 10. Mean (SE) abundances by family for vacuum net samples (n= 10).

Table 1. Sampling site numbers, dates, and UTM coordinates (WGS84, Zone 11) for paired bait-vacuum net samples (Tuolumne) and supplementary bait-only samples (Dana Meadows, Crane Flat, and May Lake).

Tuolumne Meadows

06-1-2-1-1-5	25 June 06	291731	4194426
06-1-2-1-1-6	25 June 06	291782	4194449
06-1-2-1-1-9	28 June 06	291722	4194487
06-1-2-1-2-1	30 July 06	292543	4194579
06-1-2-1-2-2	30 July 06	292531	4194538
06-1-2-1-2-3	30 July 06	291789	4194559
06-1-2-1-2-4	30 July 06	291828	4194534
06-1-2-1-2-7	31 July 06	292422	4194642
06-1-2-1-2-8	31 July 06	291661	4194314
06-1-2-1-2-10	3 Aug 06	291734	4194536

Dana Meadows

06-1-6-1	29 Sept 06	301549	4198225
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Crane Flat

06-1-6-2	12 Oct 06	253157	4182379
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May Lake

06-1-6-3	12 Oct 06	280129	4189278
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